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The effect of Nano-liquid on the properties of hardened concrete

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KEYWORDS

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Abstract Nanotechnology is one of the most active research areas that encompasses a number of disciplines including civil engineering and it may have a great impact on the field of construction materials. The literature survey shows that little is reported to evaluate the mechanical properties of concrete incorporating nano particles. This paper deals with studying the effect of Nano-liquid on the mechanical and physical properties of hardened concrete such as water permeability, absorption, abrasion resistance, compressive strength, indirect tensile strength and flexural strength. An experimental study was carried out on two types of concrete with cement content 350 and 450 kg/m^3 with water/cement ratio of 0.50 and 0.40 respectively to have a slump of 100 ± 20 mm. Concrete specimens were cured in molds for 24 h, then in water for 28 days. All specimens were subjected to drying in room temperature for 7 days before applying Nano-liquid. The used Nano-liquid was sprayed on the dry surface of hardened concrete specimens two days before testing. Hardened concrete specimens were tested according to the Egyptian standard specifications to determine the effect of Nano-liquid on mechanical and physical properties such as water permeability, absorption, abrasion resistance, compressive strength, indirect tensile and flexural strength. The experiment results show that, Nano-liquid can reduce the water absorption and coefficient of permeability. Also, it can improve the abrasion resistance of concrete, but it has no effect on concrete strength. The effect of Nano-liquid depends on concrete quality (i.e W/C ratio) and the surface condition received the Nano-liquid.

Introduction

The term ''nanotechnology'' is referred as the manufacturing, analysis and use of structures less than 100 nm (nm) in at least one dimension. Artificially produced nano-sized particles and nanoscale system components have new properties which are of importance for the development of new products and applications, Mathiazhagan and Joseph [1]. Nanotechnology is a very active research field and has applications in a number

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of areas. Recently, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering is growing. Currently this technology is being used for the creation of new materials, devices and systems at molecular, nano and micro level, Boresi et al. [2], and Mehta [3]. Permeability in cement mortars and concrete was studied extensively and tests show that the Nano-SiO_2 concrete has better water permeability, Halamickova et al. [4]. An ordinary cement system offers relatively low durability properties as a result of ease of the initiation and propagation of micro-cracks and also from the lack of tensile resistance of conventional cement mortars. Furthermore, it has been emphasized that the durability characteristics of the cement system can be greatly improved by reducing the permeability of the material. Accordingly, the permeability of concrete plays a critical role in controlling the properties of concrete and its serviceability. In this regard, an investigation was carried out by Mahyuddin et al. [5], indicated that polymer-modified cement mortars have led to enhance the permeability of the cement matrix and have significantly improved the strength and durability of cement mortars. Numerous studies on the abrasion resistance of concrete have been carried out to show that the abrasion resistance of concrete is strongly influenced by compressive strength, surface finishing techniques, curing types, aggregate properties and testing conditions. The literature survey shows that little is reported to evaluate the abrasion resistance of concrete incorporating nanoparticles. Many factors such as curing condition, concrete age, water/cement ratio, and type of aggregates have remained with unknown influence on abrasion resistance of concrete incorporating nanoparticles, Ali Nazari et al. [6]. The abrasion resistance and the compressive strength of the specimens could be improved by partially replacing Portland cement with SiO_2 nanoparticles. The enhancement of the mechanical properties is superior in the presence of SiO_2 nanoparticles as concluded by Shadi Riahi et al. [7]. Nanotechnology is one of the key technologies of the future reports and published paper. The aim of this paper is to examine the impact of Nano-liquid when sprayed on the surface of concrete on its mechanical and physical properties such as water permeability, absorption, abrasion resistance, compressive strength, indirect tensile and flexural strength.

Experimental investigation

Concrete material

Concrete mix was prepared from available local materials, natural siliceous sand, crushed dolomite from Ataka quarries, ordinary Portland cement (OPC) and tap drinking water. These materials were tested according to the relevant Egyptian Standard Specifications. The physical and mechanical characteristics of the fine and coarse aggregates are shown in Tables 1 and 2 respectively. Figs. 1 and 2 show the grading curves for the fine and coarse aggregates respectively. The test results indicate that both fine and coarse aggregates comply with the limits of Egyptian Standard Specifications No. 1109-2003 [8]. Ordinary Portland cement was used in the preparation of all concrete mixes. Table 3 shows the physical and mechanical characteristics of the used cement.

Table 1 Physical properties of fine aggregate.

Property	Results	Limits of ESS 1109 [8]
Specific weight	2.53	2.5–2.75
Bulk density (t/m^3)	1.69	–
Clay and fine dust Content (% by volume)	0.79	Not more than 3

Table 2 Physical and mechanical properties of coarse aggregate.

Property	Results	Limits of ESS 1109 [8]
Specific weight	2.5	–
Bulk density (t/m^3)	1.43	–
Water absorption%	2.49	Not more than 2.5
Abrasion index (loss anglos apparatus)%	23.37	Not more than 30

Nano liquid

The used Nano liquid material has a formulation based on water, while water and moisture are actively repelled, and materials retain their ability to ‘‘breathe’’. It is milky white water emulsion with slight odor with density of 1.01 g/cm^3. Nano liquid has a viscosity of 20 MPa/S and pH = 7.1. Its boiling temperature and flash point is more than 100 °C and auto ignition point is also more than 100 °C. Fig. 3 shows its predicting behavior when coated on concrete as described in the data sheet of the used material [10].

Experimental program

Preparation of test specimens

Two concrete mixes were used with cement content of 350 and 450 kg/m^3 and water/cement ratio (W/C) of 0.50 and 0.40 respectively to have a slump of 100 ± 20 mm. Concrete specimens were prepared and cured according to the Egyptian Standard Specification [11]. All testes were carried out at 28 days after curing. The cube specimens with dimension of $150 \times 150 \times 150$ mm are used for compression test, and cylinders of 150×300 mm are used for splitting test. Flexural strength test was carried out on $100 \times 100 \times 500$ mm prisms, while permeability test was carried out on $150 \times 150 \times 150$ mm cubes. The permeability test was carried out according to DIN. Cube samples of $75 \times 75 \times 75$ mm were prepared by cutting a big cube ($150 \times 150 \times 150$ mm) into 8 similar specimens. Small cubes of $75 \times 75 \times 75$ mm were used for water absorption test and abrasion test. Water absorption test and abrasion test were carried out on dry specimens (dried for 24 h at 100 ± 5 °C). The percentage of weight gain after immersed in water for 24 h at room temperature is considered as the absorption ratio. The abrasion test was carried out by using abrasion machine which is usually used for testing of tiles. The weight loss was measured and the loss of thickness was calculated in mm. Also the percentage of weight loss was calculated and considered as the abrasion ratio.

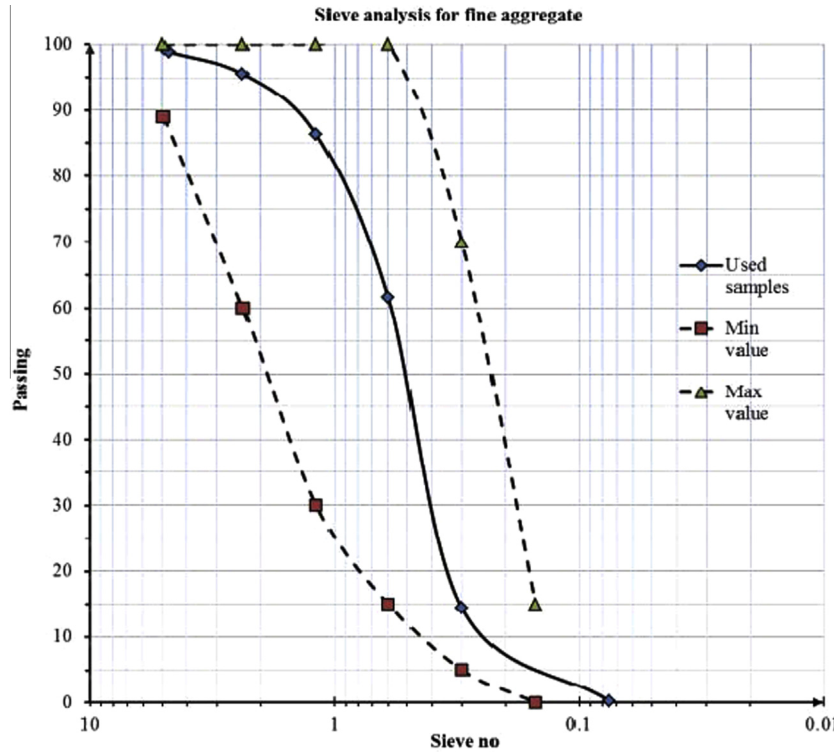

Fig. 1 Grading curve of fine aggregate.

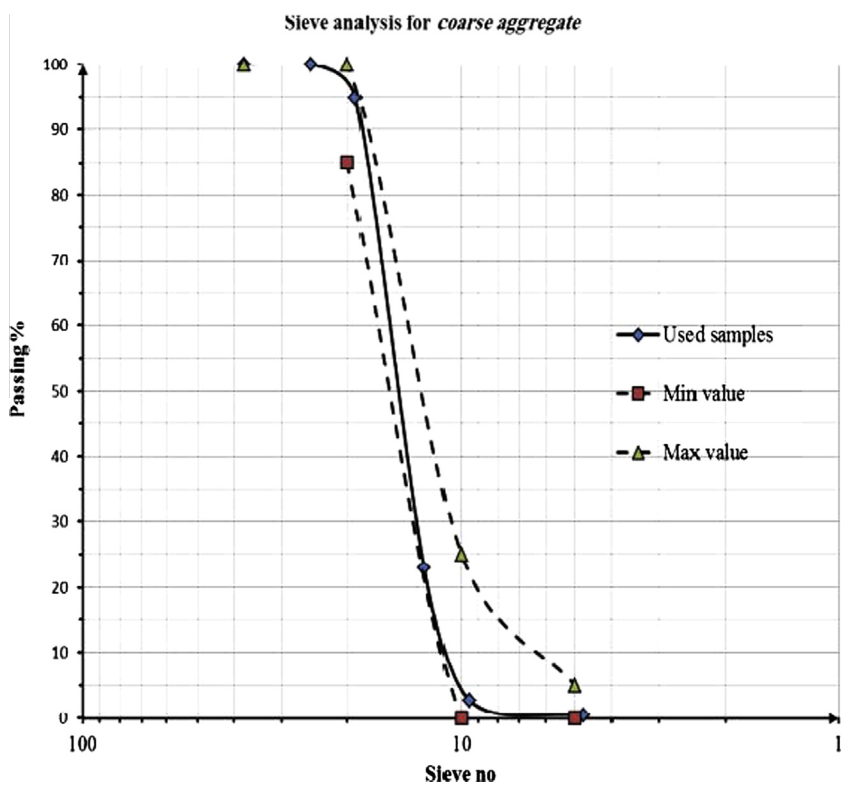

Fig. 2 Grading curve of coarse aggregate.

Application of Nano liquid

After curing concrete for 28 days in water, all test specimens were left in air for 7 days for drying, then Nano liquid was sprayed on clean dry surfaces according to the data sheet of the used Nano-liquid. Two layers of Nano-liquid were applied. The second layer of Nano-liquid was re-applied within 3 h of applying the first layer and left for 48 h before testing.

Table 3 Physical properties of ordinary portland cement.

Property		Results	Specification limits [9]
Compressive Strength of Standard mortar (MPa)	3 days	21.4	Not less than 18[a]
	28 days	39.7	Not less than 36[a]
Specific surface area (cm^2/gm)		3120	> 2750[a]
Setting time (min)	Initial	135	Not less than 45[a]
	Final	180	Not more than 600[a]

[a] Egyptian code of practice for concrete structures No. 203-2007 [9].

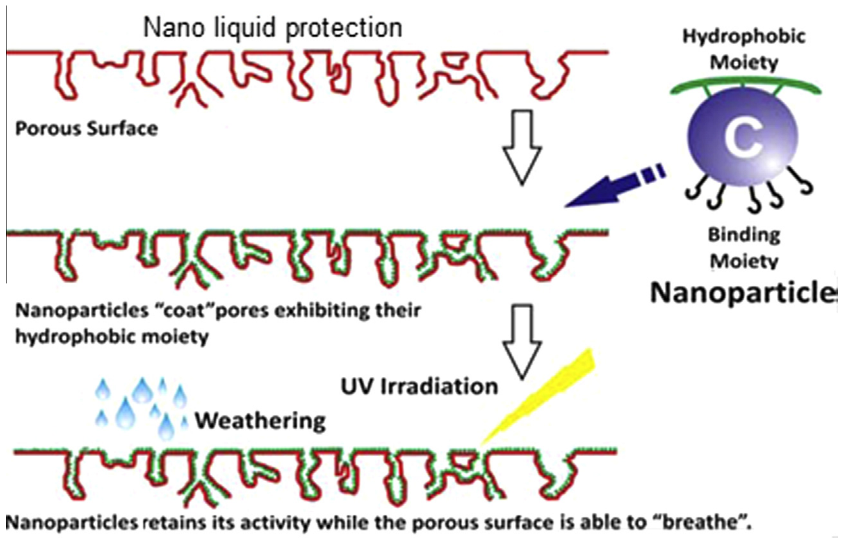

Fig. 3 Predicting behavior of Nano-liquid on concrete surface [10].

Test results

Concrete strength

The effect of Nano-liquid on compressive, indirect tensile and flexural strengths is shown in Figs. 4–6 respectively. It can be seen that there are small changes in the results of compressive strength, indirect tensile strength, and flexural strength due to the use of Nano-liquid on concrete surfaces. The changes in concrete strengths are within the test variations. Nano-liquid does not affect the strength because it was applied after 28 days of curing concrete at which the concrete reached about 95% of its strength and also, the specimens were tested after 48 h of applying Nano-liquid where Nano-liquid can only penetrate few millimeters.

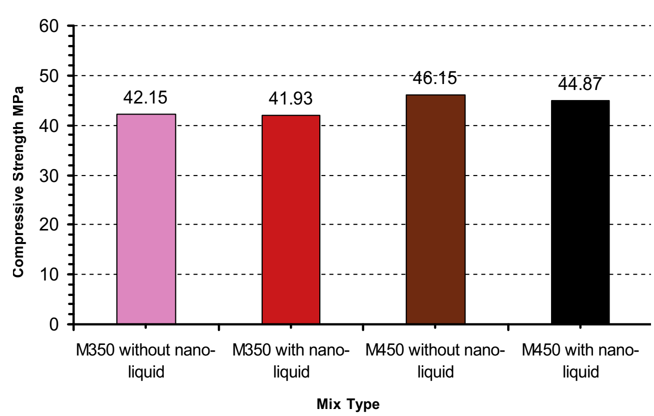

Fig. 4 Compressive strength of concrete with and without Nano-liquid.

Abrasion resistance

Figs. 7 and 8 show the effect of Nano-liquid on the abrasion resistance of concrete for outer surface (molding surfaces) and inner surface (cut surfaces) respectively. It is noted that the abrasion resistance of outer faces coated with Nano-liquid is reduced by 1.9% and 29.6% compared with those of concrete without coating for cement content 350 and 450 kg/m^3 respectively. It appears that Nano-liquid has little effect on abrasion resistance of outer faces (molding surface) of concrete containing cement content of 350 kg/m^3, this may be due to bad surface condition which contains many pores compared with rich concrete which contains 450 kg/m^3 cement content. However, the abrasion resistances of inner faces coated with Nano-liquid are reduced by 21.4% and 15.5% compared with those of concrete without coating for cement content of 350 and 450 kg/m^3 respectively. This means that the effect of Nano-liquid on abrasion resistance of concrete is affected by cement content and also by surface condition of tested specimens.

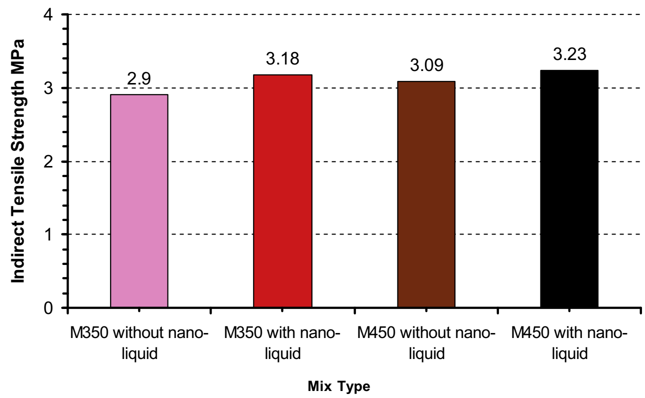

Fig. 5 Indirect tensile strength of concrete with and without Nano-liquid.

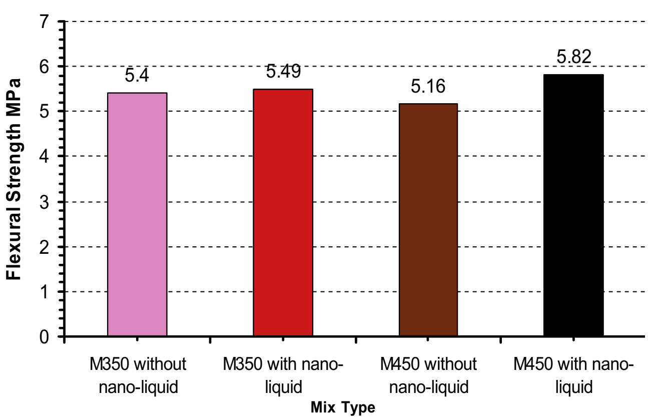

Fig. 6 Flexural strength of concrete with and without Nano-liquid.

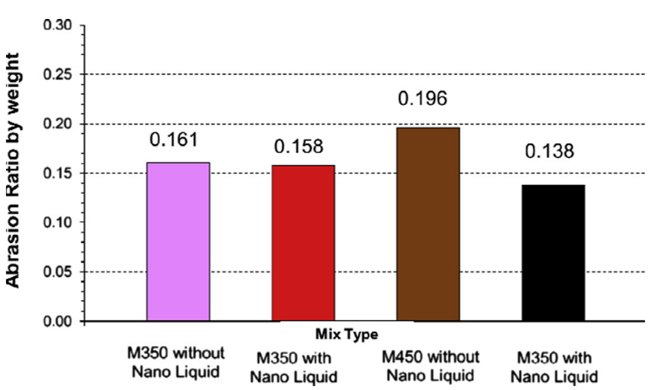

Fig. 7 Abrasion ratio by weight in outer face for concrete.

Water absorption

Fig. 9 shows the effect of Nano-liquid on the percentage of water absorption of concrete with and without Nano-liquid. The use of Nano-liquid improves the water absorption resistance by 11.9% and 9.4% for concrete having cement content 350 and 450 kg/m^3 respectively. Nano-particles fill the pores

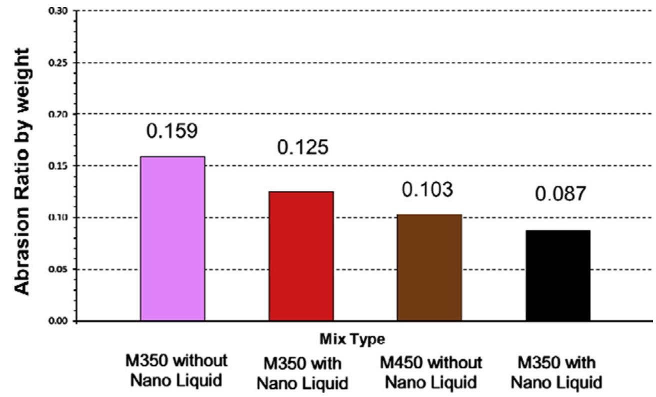

Fig. 8 Abrasion ratio by weight in inner face for concrete.

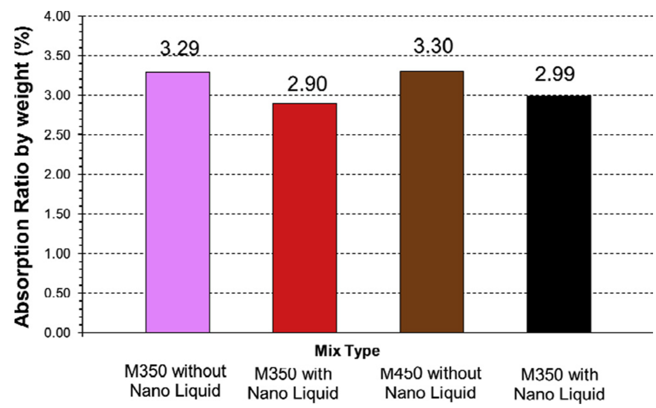

Fig. 9 Water Absorption of concrete with and without Nano-liquid.

on concrete surface and generally, water absorption resistance is improved by 10%.

Permeability of concrete

The results of permeability test indicate that coefficient of permeability of concrete was reduced from $6.856{*}10^{-7}$ to $1.938{*}10^{-7}$ when Nano-liquid was sprayed after 28 days for concrete mix containing cement content of 350 kg/m^3. The coefficient of permeability of concrete having cement content 450 kg/m^3 is $1.772{*}10^{-7}$ for concrete without coating and $1.074{*}10^{-7}$ after applying Nano-liquid.

Spraying of Nano-liquid on concrete surface reduced the permeability of concrete. This happened due to the partial filling of micro-pores and voids by Nano-liquid particles. The reductions of water permeability due to applying Nano-liquid are about 65% and 40% for concrete having cement content 350 and 450 kg/m^3 respectively. The effect of Nano-liquid is clearer for concrete having low cement content than that of higher cement content.

Conclusions

To study the effect of Nano-liquid on properties of hardened concrete, an experimental program was carried out by applying

Nano-liquid on the dry concrete surface. From experimental results the following conclusions can be drawn;

1. Nano-liquid has no effect on strength when it is applied on hardened concrete surface, however it affects other properties related to concrete surface condition.
2. The coefficient of permeability is reduced by 40% and 65% for concrete having cement content 350 and 450 kg/m^3 respectively compared with that of control specimens without applying Nano-liquid.
3. Nano-liquid reduces the water absorption of concrete by about 10%, and its effect depends on surface condition.
4. Nano-liquid improves the abrasion resistance of concrete and its effect depends on surface condition and cement content. In general, the cut surfaces have higher abrasion resistance than uncut surfaces (molding faces).

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